VRVision User Manual

Version 1.07

James Ward
University of Hull, UK
20th May 2003

Last updated: 1st August 2004

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1. Introduction

VRVision is a MEX plug-in for Matlab, which allows 3D scenes to be displayed in real-time, with controllable lighting, perspective and photo texturing. Scenes can be presented in true stereoscopic 3D, and with a dynamic viewpoint that accounts for the head position of the viewer. It directly supports VRML1 and OpenInventor file formats, and other formats can be read by using third party file converters.

The software was originally designed for use by Psychologists in behavioural research experiments. It was conceived as a replacement for databases of pre-rendered 2D images that were typically prepared using packages such as 3D Studio MAX (Discreet) or Maya (Alias Wavefront). With VRVision, it is possible to display 3D scenes in real-time, and to vary the conditions (such as lighting, orientation, texturing, animation) during the course of an experiment. This can be achieved without the need to generate large databases of images, and can therefore save a lot of time and effort on the part of the researcher.

VRVision was designed for use with existing software such as Matlab and the PsychToolbox, which have become popular for this type of study.

2. Requirements

2.1. Software Requirements

The basic requirements are as follows:

Operating System: Windows 2000 (recommended) or Windows XP

Matlab Version: Matlab 6.1 or greater

Optional Software: Psychophysics Toolbox (PsychToolbox)

The current version of VRVision has been developed on Windows 2000, and has also been used successfully on Windows XP. Other versions of Windows such as 95/98/ME/NT have not been tested, and are not recommended. The VRVision software is reasonably portable, and we plan to develop versions for other operating systems (MacOS X, Linux) in the future.

The development work was carried out in Matlab 6.1, and the software has also been tested in Matlab 6.5. Later versions of Matlab are probably compatible, but are untested at time of writing.

It is recommended that you download and install the excellent PsychToolbox, since this will give you the most flexibility when constructing experimental programs. It is then possible to use PsychToolbox to display 2D images and user interface displays, then use VRVision to display 3D scenes and for stereoscopic display as appropriate. It would equally be possible to use the Matlab windowing system to construct user interfaces, but you might find PsychToolbox more suitable (for example, it is difficult to make true full screen windows with Matlab).

2.2. Hardware Requirements

The hardware requirements are highly dependent upon which features of VRVision you wish to use. The program should be usable in its basic form on most PCs. However, if you wish to display complex 3D scenes (thousands of polygons, texture maps etc.), then a reasonable minimum specification is:

Pentium III 1GHz CPU

256Mb RAM

nVidia GeForce 2 MX graphics card (note: does not support stereoscopic display)

If you wish to use the stereoscopic display feature, then you will also need a graphics card that supports quad-buffer OpenGL stereo, and an appropriate display device. For more details, please refer to Section 7, which covers the topic in more detail.

Similarly, if you wish to use the head tracking feature, then you will need access to one of the tracking systems that are supported by VRVision which are listed in Section 9.

3. Installation

The VRVision software can be downloaded from the web-site as single ZIP file, which contains all the files needed to get you started. You can download the software from the following address:

http://www.hive.hull.ac.uk/software/vrvision

Having downloaded the software, you can unzip all the files into the Matlab\work folder, and restart Matlab. If you don't want to place these files in your work folder, you can create a new folder and alter the Matlab search path accordingly.

The following is a step by step installation example:

1. Download the complete VRVision software as a ZIP file.
2. Unzip the files into the Matlab working directory. You can install them in another directory if you wish, but make sure that it is in the Matlab search path.
   For example:
   ```
   c:\matlab6p5\work
   ```
3. Restart Matlab to make sure that the vrvision module is loaded.

VRVision itself is a standard Matlab MEX file, which consists of a Windows DLL. This DLL must be in the Matlab MEX search path, so that it is found when 'vrvis' is typed at the Matlab prompt. The ZIP file includes a number of other DLL files that are needed by VRVision, as well as an initialisation (INI) file and a sample scene. It is important that all the files are installed, otherwise VRVision will not load.

The INI settings file must be placed in the same working directory as the VRVision DLL. However, the remaining files can be placed anywhere in the Windows search path. For example, you can place them in the Windows system directory or create a new folder and add it to the Windows search path.

After changing file locations and search path settings, it might be necessary to restart Matlab for the changes to take effect.

4. Getting Started

For those who dislike reading lengthy instructions, here is a very brief introduction to get you started:

1. Install VRVision as described in Section 3.
2. Obtain an OpenInventor or VRML 1.0 model (file extension .iv or .wrl). There are some sample files provided on the web-site:

   http://www.hive.hull.ac.uk/software/vrvision

   Note that VRML97 / VRML 2.0 are not currently supported by SGI OpenInventor.
3. Your scene may be too big or too small to display by default, or it may be positioned far away from the origin. Also, if your scene doesn't contain lights, you should turn on the headlight.

   For these reasons, when running VRVision for the first time you might want to use a text editor (e.g. notepad) to edit some of the settings in the 'vrvision.ini' file to match the ones shown here:

   ```
   [Scene]
   Headlight=1    ; turn on the headlight
   Scale=auto     ; use automatic scaling
   AutoCentre=1   ; automatically move scene to origin
   ```
4. Start Matlab normally.
5. Instruct VRVision to load the scene, and display it:

   ```
   >> vrvis('SetFilename', 'yourscene.iv')
   >> vrvis
   ```

If that was successful, you will find the other supported functions documented in Section 5. The best way to understand what is possible, and how to use the supported functions, is to work through the different commands in the function reference at a Matlab command prompt. In this way, you can immediately see the effect of the different options on the behaviour of VRVision.

5. Function Reference

This section lists the functions supported by VRVision, explains their parameters, and provides some examples of how they can be used in practice. All the examples shown here are typed at the Matlab prompt, or called from within a Matlab program (M file).

There are two ways that VRVision can be called. The first one is to call the main function without any parameters. You can either use the full name of the function ‘vrvision’ as shown here:

```
>> vrvision
```

Alternatively, you can use the shorthand:

```
>> vrvis
```

This will start the main VRVision application, and display the current 3D scene. However, before doing this you would normally need to set up some parameters, for example to specify which scene file to load. There are a number of functions provided for this purpose.

Every function consists of a call to VRVision, with the name of the function passed as a text string, followed by an optional list of parameters. For example, to call the SetFilename function:

```
>> vrvis(‘SetFilename’, ‘myscene.iv’)
```

Functions fall into two main categories:

1. Setup: functions that set parameters, before running VRVision.
2. Query: functions that retrieve data or results after VRVision has finished running.

5.1. Setup Functions

These functions can be called before the application runs, to configure various settings, such as which scene file to load or the viewer position. Most of these settings will persist between successive runs of VRVision, unless stated otherwise. Many of them are also configurable from within the INI file, in which case the INI file setting acts as a default that is overridden when you change the setting from within Matlab.

SetFilename

Specifies which 3D scene file should be loaded when VRVision runs. If no file is specified, the filename given in the INI file will be used instead. The current version directly supports files with the following formats:

VRML 1.0

OpenInventor 2.1 (ASCII or binary)

Examples:

```
vrvis('SetFilename', 'filename.wrl')
vrvis('SetFilename', 'filename.iv')
vrvis('SetFilename', 'samples/robot.iv')
```

Note: the path separator is '/', for example: 'folder/file.iv'.

SetModifier

You can specify an optional *modifier* to the 3D scene. The modifier is simply another Inventor/VRML file that is loaded immediately before the 3D scene (in technical terms, the

3D scene becomes a child node of the modifier). Therefore, any Inventor nodes in this file will affect the scene.

This is mainly a convenience for the user, since the same scene file can be loaded under a number of different modifiers to achieve different results. This is a very powerful feature, and has many possible applications:

- Animation. For example, to make a scene rotate automatically.
- Lighting. For example, to view the same scene with different lighting conditions.
- Resize / Reposition. Scale or translate the scene before display.
- Display styles. For example, to modify the draw style: wireframe, points etc.

It is probably simpler to explain this with an example:

1. Create a text file called ‘wire.iv’ containing the following text:

```
#Inventor V2.1 ascii
DrawStyle {
   style LINES
}
```

   You can use any text editor to do this (notepad for example).

2. Set up VRVision to use this as a modifier:

```
vrvis(‘SetModifier’, ‘wire.iv’)
```

3. Now, when you use VRVision normally to display a scene:

```
vrvis(‘SetFilename’, ‘yourscene.iv’)
vrvis
```

   You should see that the scene is displayed in wireframe.

The proper use of modifiers can simplify the process of setting up several different experimental conditions without modifying the scene file itself. For example, in a face recognition study, the scene files would contain the VRML face models, and the modifiers might specify different lighting conditions.

Some understanding of OpenInventor or VRML nodes is needed to be able to make the best use of this feature.

SetViewPos

Sets the default viewer position (X,Y,Z coordinates in metres). This will be used in preference to the value given in the INI file under the [Camera].Position key (the INI file settings are explained in more detail in section 7). If head tracking is enabled, the viewer position is controlled by the tracking system instead.

This setting will typically be used when the viewer is always in a fixed viewing position, for example when seated in front of the screen, or if a chin rest is used to position the head.

If you call 'SetViewPos' without arguments, it restores the default setting from the INI file.

The origin (0,0,0) is the centre of the screen. From the point of view of the user, the X axis points right, the Y axis up, and the Z axis points out of the screen.

For example, to place the viewer 2m distant from screen:

```
vrvis('SetViewPos', 0,0,2)
```

To restore the INI default setting, call the function without any parameters:

```
vrvis('SetViewPos')
```

SetScenePos

Specifies the scene position, as an X,Y,Z translation in metres. If the AutoCentre option is enabled (in the INI file) this translation will be applied after the auto-centre. Therefore, you can combine these two options. However, if you want to specify an absolute translation for the object in world coordinates, you should ensure that AutoCentre is first disabled (otherwise your translation will be made relative, after the object has first been moved to the origin).

For example, to move the object 1m behind the screen (assuming that it is normally located at the origin):

```
vrvis('SetScenePos', 0,0,-1)
```

The origin (0,0,0) is the centre of the screen. From the point of view of the user, the X axis points right, the Y axis up, and the Z axis points out of the screen.

SetScale

This function sets the scene scale factor. This will be used in preference to the value given in the INI file. For example, to set an absolute scale of $1/10^{th}$ normal size:

```
vrvis('SetScale', 0.1)
```

The size on screen may be affected by the following:

- Object dimensions in the scene file.
- Screen size settings in the INI file.
- Scale factor (either from INI file, or the SetScale function).
- The viewer / object position relative to the screen.

SetAngleX

Applies a rotation about the X-axis (right axis), given an angle in degrees. The rotation angle can be positive or negative.

For example, to rotate the scene by 45 degrees:

```
vrvis('SetAngleX', 45)
```

This function is a convenience to the user. If you want to perform more general, or more complex, transformations then an alternative is to use the modifier feature (see *SetModifier* function for details).

SetAngleY

Applies a rotation about the Y-axis (vertical axis), given an angle in degrees. The rotation angle can be positive or negative.

For example, to rotate the scene by 45 degrees:

```
vrvis('SetAngleY', 45)
```

This function is a convenience to the user. If you want to perform more general, or more complex, transformations then an alternative is to use the modifier feature (see *SetModifier* function for details).

SetBackCol

This function allows the background colour of the scene to be changed. The default is to use a black background. The colour is specified as three values: Red, Green and Blue, each in the range zero to one.

Examples:

```
vrvis('SetBackCol', 1,1,1) ; white background
vrvis('SetBackCol', 0.5,0,0)     ; medium red background
vrvis('SetBackCol', 0,0,0) ; black background
```

Note: if you enable the underlay mode (see documentation of *UseUnderlay* function), the background colour will be ignored.

UseStereo

This function determines whether the application should run with or without stereoscopic display (for example, using LCD shutter glasses). Not all hardware is capable of running in stereo. If stereo is not supported, VRVision defaults to the normal mono display mode.

Examples:

```
vrvis('UseStereo', 1)      ; enable  stereo (if possible)
vrvis('UseStereo', 0)      ; disable stereo (the default)
```

For more details about the hardware requirements for stereo support, please refer to Section 7.

UseHeadTrack

This function enables head-tracking, if a suitable tracking system is first connected and properly configured. When enabled the display is continuously updated to provide an appropriate view for the current head position of the viewer. In particular, if stereo mode is also enabled, the left and right eye positions of the viewer are calculated and used to provide two different projections (using an asymmetric viewing frustum). Please refer to Section 9 for further details.

Examples:

```
vrvis('UseHeadTrack', 1)         ; enable head tracking
vrvis('UseHeadTrack', 0)         ; disable head tracking
```

UseTimeLimit

Specifies a time limit in seconds, after which the application will automatically close. This can be used to display a particular 3D scene for a limited time period.

Examples:

```
vrvis('UseTimeLimit', 12.5)       ; display for 12.5 seconds
vrvis('UseTimeLimit', 0)          ; disable the time limit
```

UseQuitKeys

This function allows you to specify which keys can be used to quit from the application. When the application quits, it will return to Matlab. The default is to disable quit keys, except for the ESC key (which can always be used to quit).

You can specify a character string, listing the acceptable quit-keys, or you can specify the special string 'any' which will accept (almost) any key on the keyboard.

Examples:

```
vrvis('UseQuitKeys', 'abcdef')    ; quit when keys A-F pressed
vrvis('UseQuitKeys', 'any')       ; quit when "any" key pressed
vrvis('UseQuitKeys', 0)           ; disable keyboard quit
```

If the user quits by pressing a key, it is possible to find out the elapsed time and the key that they pressed using the following two functions:

```
GetQuitKey
GetQuitKeyTime
```

UseMouseMove

This function allows you to rotate the scene using the mouse. If enabled, horizontal movement of the mouse will rotate the scene about the Y axis (azimuth), and vertical movement will rotate the scene about the X axis (elevation). The range of movement on each axis can be specified in terms of a maximum angle. For example, specifying an angle of 45 degrees will allow the model to be rotated between -45 and +45 degrees. You can lock a particular axis (prevent rotation on that axis), by specifying an angle limit of zero.

Examples:

```
vrvis('UseMouseMove', 1)          ; enable mouse movement
vrvis('UseMouseMove', 0)          ; disable mouse movement
vrvis('UseMouseMove', 1, 45,0)    ; allow 45° rotation about X
vrvis('UseMouseMove', 1, 0,45)    ; allow 45° rotation about Y
vrvis('UseMouseMove', 1, 15,15)   ; allow 15° rotation about X+Y
```

Mouse rotation can be recorded to file and replayed later. Please see the *RecordToFile* and *PlayFromFile* functions for further details.

UseJoyMove

This function allows you to rotate the scene using a joystick or trackball. Most devices that appear as a standard game controller within Windows should be compatible with this option. This function supports the same rotation angle limits as the *UseJoyMove* function, including the ability to lock an axis by specifying an angle limit of zero.

When using the joystick for movement, you can also use the joystick buttons. Please see the *UseJoyQuitKeys* function for details.

Examples:

```
vrvis('UseJoyMove', 1)            ; enable joystick movement
vrvis('UseJoyMove', 0)            ; disable joystick movement
vrvis('UseJoyMove', 1, 45,0)      ; allow 45° rotation about X
vrvis('UseJoyMove', 1, 0,45)      ; allow 45° rotation about Y
vrvis('UseJoyMove', 1, 15,15)     ; allow 15° rotation about X+Y
```

Joystick rotation can be recorded to file and replayed later. Please see the *RecordToFile* and *PlayFromFile* functions for further details.

UseJoyQuitKeys

This function allows you to specify which joystick buttons/keys can be used to quit from the application. When the application quits, it will return to Matlab. The default is to disable quit keys.

You can specify a character string, listing the acceptable button numbers, or you can specify the special string 'any' which will accept any button press on the joystick. Button numbers range from 0 to 9 inclusive, with 0 being the first joystick button. The numbering of buttons will vary from one joystick to another. Some joysticks provide a utility for reassigning buttons at driver level.

Examples:

```
vrvis('UseJoyQuitKeys', '01')     ; quit if button 0 or 1 pressed
vrvis('UseJoyQuitKeys', 'any')    ; quit when "any" key pressed
vrvis('UseJoyQuitKeys', 0)        ; disable joystick quit
```

If the user quits by pressing a key, it is possible to find out the elapsed time and the key that they pressed using the following two functions:

```
GetQuitKey
GetQuitKeyTime
```

To distinguish the joystick buttons from any other key on the keyboard, these functions return special names for each button ranging from ‘JOY0’ through to ‘JOY9’.

UseFullScreen

This allows you to select either full-screen mode, or to display in a window (which can be moved or resized). The default is to run full-screen. When running in full-screen mode, VRVision will force itself on top of all other windows.

Examples:

```
vrvis('UseFullScreen', 0)         ; run in a window
vrvis('UseFullScreen', 1)         ; enable full-screen
```

UseUnderlay

This function is used to enable a special 'underlay' mode, which causes the entire desktop contents to be screen captured as VRVision starts. This screen capture is then used as a background image when drawing the 3D scene.

For example, you can use the SCREEN function in PsychToolbox to draw some background graphics, then enable the underlay mode and start VRVision. When VRVision starts, the 3D scene will appear superimposed on top of the drawing that you did previously.

Examples:

```
vrvis('UseUnderlay', 1)         ; enable underlay mode
vrvis('UseUnderlay', 0)         ; disable underlay (the default)
```

When underlay is enabled, the screen is captured just before VRVision appears. Therefore, you should do your drawing just before running VRVision. The underlay feature only really makes sense when VRVision is running in fullscreen mode, otherwise the screen contents will be displayed in a much smaller window.

VRVision uses one of two methods to display the underlay:

1. Texture map method.
2. Blitter method.

The quality and speed of the two methods will vary between different graphics card and driver combinations. In fact, the texture map method may not work at all if your graphics card cannot create texture maps at full screen resolution. Therefore, you should pick the method which works best on your card. You can do this by modifying the INI file as described below.

Under the [Scene] section of the INI file, use either of the following keys:

```
UnderBlit=0    ; use texture map method (OpenGL texturing)
UnderBlit=1    ; use blitter method (OpenGL glDrawPixels)
```

If this option is missing from the INI file, the default is to use the texture map method.

RecordToFile

This option causes the camera movement and/or mouse movement to be recorded to file, so that it can later be analysed or replayed. It is typically used in conjunction with head tracking. For example, the data could later be used to examine the motion of the users head during a particular task.

The function takes a single parameter: the filename to record to. If the file already exists, it will be overwritten. If the 'PlayFromFile' option is also specified, then it will take precedence over recording.

This function applies only to the next run of VRVision, after which recording is cancelled. Therefore, if you want to record every time, you must specify this option prior to each run (which would be necessary in any case, to avoid overwriting the last file).

Examples:

```
vrvis('RecordToFile', 'filename')
```

PlayFromFile

This option is used to play back camera or mouse motion that has previously been recorded to file using the *RecordToFile* function. The function takes a single parameter: the filename to play back.

This function applies only to the next run of VRVision, after which playback is cancelled. If head tracking was enabled as well, the file playback will take precedence. Optionally, you can specify 'quit' to make the application close at the end of playback.

Examples:

```
vrvis('PlayFromFile', 'filename')
vrvis('PlayFromFile', 'filename', 'quit')
```

DumpPos

This option forces the position and orientation data received from the head tracker to be dumped to the text console within Matlab. This function is only really useful for a developer; it is useful for debugging or calibrating the tracking system. For example, to calculate the TrackerXForm or GlassesXForm parameters for the INI configuration file.

Examples:

```
vrvis('DumpPos', 1)  ; enable
vrvis('DumpPos', 0)  ; disable (default setting)
```

5.2. Query Functions

These functions are called after VRVision has finished displaying the scene, and returned control to Matlab. They are used to retrieve information from VRVision, such as which key was pressed to quit, or the elapsed time until the user hit the key.

GetQuitKey

This function returns the key that the user pressed to quit. It will only contain a valid key if the key-quit option has first been enabled with the *UseQuitKeys* function. The key is returned as a character array (string). To distinguish the joystick buttons from any other key on the keyboard, they are named ‘JOY0’ through to ‘JOY9’.

Example:

```
k = vrvis(‘GetQuitKey’)
```

GetQuitKeyTime

This function returns the time in seconds that elapsed between the first drawing that the application did (onset of stimulus), and the user pressing one of the accepted quit keys. The resolution and accuracy are system dependent. There is more information about timing accuracy on the VRVision web-site.

If the user didn't press a key, this function will return zero.

Example:

```
t = vrvis('GetQuitKeyTime')
```

6. Scene Files

This section briefly describes some of the effects that can be achieved by creating and editing OpenInventor or VRML scene files.

6.1. Lighting

In common with most real-time graphics applications, VRVision uses a relatively simple lighting model. This is sufficient for simple lighting effects, including directionality of light, intensity and colour. It does not include effects such as shadows at present.

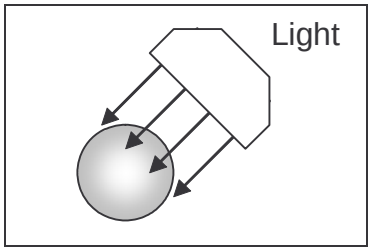
VRVision supports three different types of light source:

- Directional Light
- Point Light
- Spot Light

As a special case, it is also possible to disable lighting so that the object colour and photo texture are used directly. For example, if a texture map already includes natural lighting and shadows, this can be displayed directly without use of an additional synthetic light source.

Directional Light

The directional light source is considered to be at an infinite distance from the subject, so that the 'rays' of light can all be treated as being parallel. Therefore, the light source is specified only as a direction vector. The closest real world analogy would be the sun illuminating an object on the earth.



The light source is defined in the Inventor (.iv) file as follows:

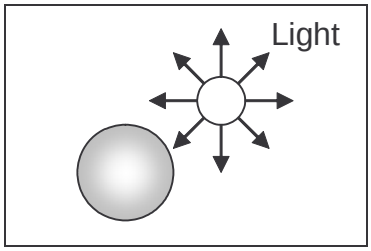
```
DirectionalLight {
    direction 0 0 -1
}
```

The direction of the light source is specified by a *vector*, consisting of three values. These represent the X, Y and Z components of the vector. In the example above, the direction is set to the negative Z axis, which causes the light to point into the screen. This will cause the scene to be evenly lit from the front.

The three components of the direction vector allow the light to be aimed in any direction you wish. Preferably, the direction vector should have unit length. That is to say, the sum of the squares of the three components should add up to one.

Point Light

The point light source emits light equally in all directions from a specific point. For example, imagine a soft light bulb, floating in space. The exact position of the light can be specified.



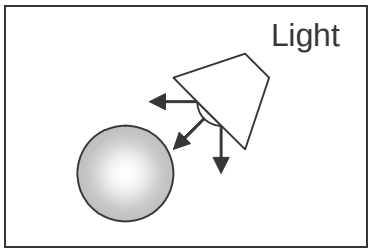
The light source is defined in the Inventor (.iv) file as follows:

```
PointLight {
    location 0 0 1
}
```

The location (position) of the light source is specified again by a *vector*, consisting of three values. These represent the X, Y and Z co-ordinates of the light source. In the example above, the light is located at one unit on the Z axis. For our purposes, this places our light one metre out from the centre of the screen. Increasing the X component (the first value) would move the light to the right, and increasing the Y component (the second value) would move the light up.

Spot Light

The spot light has a particular position in space, but also has a direction of illumination. For a real world analogy, consider a desk lamp with a shade. This type of light projects light in a particular 'cone'.



The light source is defined in the Inventor (.iv) file as follows:

```
SpotLight {
    location 0 0 1
    direction 0 0 -1
    dropOffRate 0
    cutOffAngle 0.785
}
```

The **location** (position) of the light source is specified again by a *vector*, consisting of three values that represent the X, Y and Z co-ordinates of the light source (see PointLight).

The **direction** vector specifies which direction the light is aimed in (see Directional Light above).

The **cutOffAngle** is the angle (in radians), measured from the direction vector, where the cone of light will be cut off. This can be considered as the angle of the 'lampshade' in the diagram above. In the example above, the angle is set to the default value of 45° (PI/4 ≈ 0.785).

The **dropOffRate** is the rate at which the light intensity drops off (decreases) as the angle between the ray of light and the direction vector increases. The value must be between 0 where the cone of light has equal intensity throughout, and 1 which specifies a narrow beam of light.

Common Light Properties

There are some common properties that apply to all of the light types described above. These allow the intensity and colour of the light to be adjusted, and allow a particular light to be turned off and on.

The following example illustrates the default settings for the three common properties on a directional light source. They are equally applicable to point and spot lights.

```
DirectionalLight {
    on TRUE
    intensity 1
    color 1 1 1
}
```

The **intensity** value allows the brightness of the light source to be adjusted. The valid range is from 0 (no light) to 1 (maximum brightness).

The **color** value specifies the colour of the light source in terms of three separate components: red, green and blue. Each component ranges from 0 (minimum) to 1 (maximum). Some typical colours are listed in the table below:

R	G	B	Colour
0	0	0	Black
1	0	0	Red
0	1	0	Green
0	0	1	Blue
1	1	0	Yellow
0	1	1	Cyan
1	0	1	Magenta
1	1	1	White

The light can be turned on and off by setting the **on** property to TRUE or FALSE respectively. This feature is probably not very useful for this application.

Material Properties

The material properties of objects within the scene must be carefully considered to achieve the desired appearance. For example, it is possible to achieve gloss or matte surface qualities, to control object self illumination (glow / emissive lighting), and rudimentary transparency effects.

In some cases, the material properties might already be contained within the scene file, particularly when it has been exported from a 3D modelling package.

It is possible to specify custom material properties by adding the following text to a scene file or modifier. However, bear in mind that your settings might later be overridden by settings within the scene file itself.

```
Material {
    ambientColor 0.1 0.1 0.1
    diffuseColor 0.7 0.7 0.7
    specularColor 0.3 0.3 0.3
    emissiveColor 0 0 0
    shininess 0
    transparency 1
}
```

The **ambientColor** value is a simple colour value that simply adds to the apparent brightness of the object, and does not consider the lights within the scene. It is specified as three values in the range 0 to 1, representing the Red, Green and Blue components of the colour.

The **diffuseColor** determines the diffuse surface colour of the object when lit. It is specified as three values in the range 0 to 1, representing the Red, Green and Blue components of the colour.

The **specularColor** determines the specular colour when lit. It is specified as three values in the range 0 to 1, representing the Red, Green and Blue components of the colour.

The **emissiveColor** determines the colour of the light emitted by the object. It can be used to cause an object to appear to be self-illuminated, without external lighting. It is specified as three values in the range 0 to 1, representing the Red, Green and Blue components of the colour.

The **shininess** value controls the appearance of specular highlights on the object. It ranges from 0 (which gives a dull, matte appearance), to 1 (which produces glossy looking surfaces).

The **transparency** value ranges from 0 (completely opaque), to 1 (completely transparent). When completely transparent, the object will be invisible. Intermediate values will make the object semi-transparent.

Multiple Light Sources

It is possible to specify multiple light sources within a scene file, and these can be of different types. The number of supported lights, and the resultant performance, will vary significantly from one machine to another (depending on the graphics card).

Base Colour Lighting

It is possible to apply a texture map to the scene that includes lighting and/or shadows, perhaps from digital photographs, or pre-rendered material. In this case, it can be desirable to use the texture map colour values directly, and to disable external light sources.

This can be achieved by inserting the following into the scene file:

```
LightModel {
    model BASE_COLOR
}
```

When specifying this lighting model, there is no need to specify any additional light sources, or to enable the headlight in the INI file, since the texture map colour will be used directly.

Instead of modifying the original scene file, it would be better practice to create a separate modifier file, containing the light model settings. An example of a typical modifier file (called ‘unlit.iv’) is shown below:

```
#Inventor V2.1 ascii

LightModel {
    model BASE_COLOR
}
```

From within Matlab, you can then specify the original scene file and the modifier as follows:

```
vrvis('SetFilename', 'YourScene.iv')
vrvis('SetModifier', 'mod_unlit.iv')
```

When the VRVision viewer is next started, the chosen modifier will be applied before loading the scene file, so that lighting will be disabled. This technique makes it possible to apply any number of different lighting conditions to the original scene file.

Animated Light Sources

It is possible to animate light sources by using the OpenInventor engines, such as the **ElapsedTime** and **Calculator** nodes. For example:

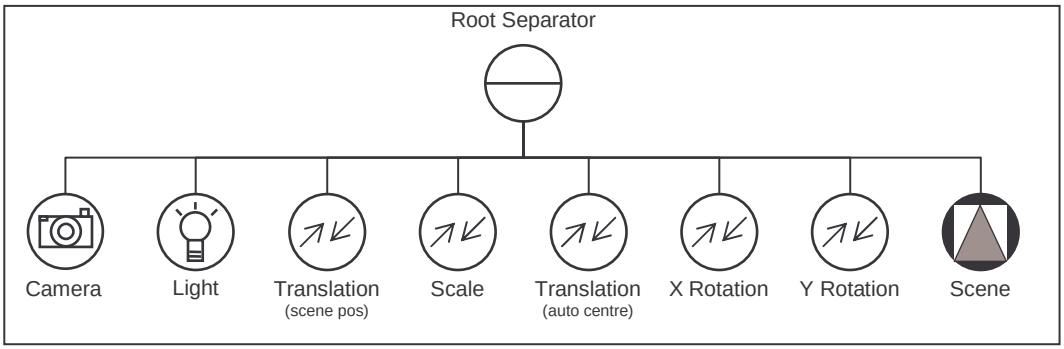
1. Vary light intensity as a function of time.
2. Turn lights on and off in sequence.
3. Move lights along a predefined path.

6.2. The Scene Graph

Internally, VRVision builds an Open Inventor *scene graph* that describes the scene to be displayed, and determines the order in which various transformations (such as rotation, scaling and translation) are applied to the scene. This section illustrates the typical structure of this scene graph, and how it is affected by various options given to VRVision.

Default Scene Graph

The figure below shows the scene graph in the default state, without any options specified in the INI file. Note that the X and Y rotation nodes are immediately before the Scene. This means that any rotation (for example, using the *SetAngleY* function) will take place about the origin of the scene itself. i.e. as it appears in the Inventor or VRML scene file.



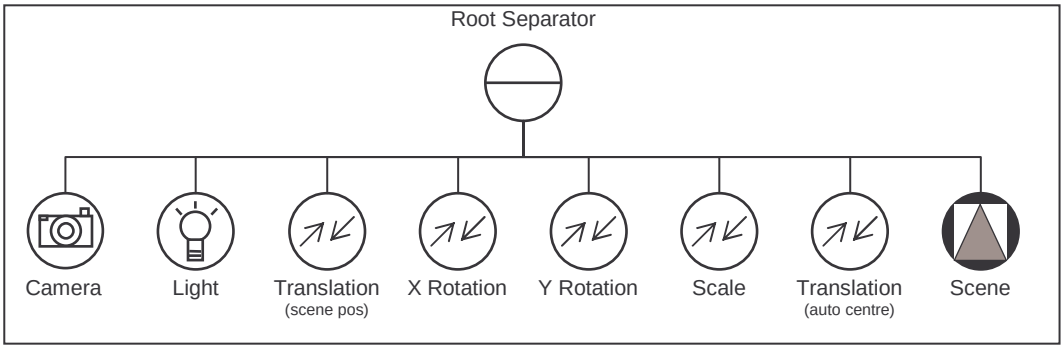
You can select this behaviour by specifying the following options in the INI file before starting VRVision:

```
[Scene]
RotateFirst=0     ; this is the default
```

This is the default behaviour; if the RotateFirst option is not specified in the file, it is assumed to be zero (disabled).

Rotate First Option

There is an option in the INI file that can be used to force the X and Y rotation nodes to be inserted before the Translation (auto centre). This means that if both the ***auto centre*** and the ***rotate first*** options are enabled in the INI file, the scene will be automatically repositioned at the origin (based on the scene bounding box), and then rotated. The resulting scene graph is shown below.



These options are very useful if the VRML or Inventor scene file has an origin that does not lie near the centre of the object. You can select this behaviour by specifying the following options in the INI file before starting VRVision.:

```
[Scene]
AutoCentre=1      ; enable automatic centre option
RotateFirst=1     ; rotate before translate
```

Note that this is only a small extract from the INI file. There are many more options detailed in section 7.

6.3. The Open Inventor File Format

This section contains some background information about the Open Inventor file format, as used by VRVision. This is too large a topic to cover in detail here, but after reading these few examples, it should be possible to construct and edit some simple scenes and to have a basic understanding of the structure and capabilities of Open Inventor files.

The Open Inventor 2.1 file format (Silicon Graphics Inc.) supports a plain text ASCII format, as well as a binary format which is more compact and loads faster. This section will concentrate on the plain text format, which makes it relatively easy to edit and create Open Inventor files manually. It is also possible to create them automatically from within a Matlab script, and an example of such a script (ivsurf.m) is provided on the VRVision web-site.

Although this section describes only the Open Inventor file format, it is worth mentioning that the VRML file format is based on Open Inventor, and is therefore very similar. The Open Inventor library (and VRVision) can load VRML1 files, but not VRML2 / VRML97 files. This is a limitation of the open source version of Open Inventor 2.1. It future it would be possible to recompile VRVision to work with the commercially available Open Inventor 3.1 or later, which is sold by Template Graphics Software (www.tgs.com), and which does support VRML2. Alternatively, the Coin3D library from Systems in Motion also supports VRML2. This is an Open Inventor work-alike, which is available under both open source and commercial licenses.

Example 1: Creating a Cube

Open Inventor has built in support for a number of simple primitive objects, such as cubes, cylinders, spheres and cones. We can create a file that contains one or more of these objects very easily.

Start by using a text editor to create a new text file. Enter the text shown below, being careful to copy it exactly as shown:

```
#Inventor V2.1 ascii
Cube {
}
```

Save this file as ‘cube.iv’. The .iv file extension indicates that this is an Open Inventor file, as does the first line of the file. You may find that some text editors will not allow you to change the file extension, and may automatically add the ‘.txt’ extension by default. If this happens, it may be necessary to rename the file after saving.

When you have saved the file, you can try loading it into VRVision from the Matlab prompt as shown below:

```
>> vrvis('SetFilename', 'cube.iv')
>> vrvis
```

To ensure that the cube is visible, it is suggested that the automatic scaling feature is enabled in the initialisation file. Otherwise, the SetScale command can be used from within Matlab to adjust the scale.

In the example above, the first line is a special header that indicates that this is an Inventor file, including a version number and that it uses the ASCII (plain text) format. All the examples shown here will include this header.

The remainder of the file describes the *scene graph*. In this case, the scene graph consists of just a single *node*, which is a cube. You will notice that after the name of the node ‘Cube’, there is an open and closed curly bracket ‘{‘ and ‘}’. Every node has a number of *fields*, which are usually parameters such as width, height, depth or radius. You can set these fields to a particular value by listing the field names and values between the curly brackets.

For example, the cube node has *width*, *height* and *depth* fields. You can set them as shown below:

```
#Inventor V2.1 ascii
Cube {
   width  1
   height 0.5
   depth  0.25
}
```

Try modifying the file with a text editor, so that you can see the effect of these fields. Note that if you don’t set a particular field value, the default values will be used instead.

Example 2: Transformations

It is possible to move, rotate or scale objects within the scene graph. This is achieved by inserting one or more *transformation nodes*. Some examples of transformation nodes are listed below:

RotationXYZ	- rotate a node about the X,Y or Z axis
Scale	- change the scale of a node
Translation	- move an object (change the position)

You can apply multiple transformations to an node, for example to change both the scale and position of an object. The transformations will be listed in the Inventor file in the order that you wish to apply them. The node or object that you wish to transform should appear after the transformation node(s).

For example, we can modify the ‘cube.iv’ file seen in example 1 so that the cube is rotated by 45 degrees about the Y axis. This involves adding a **RotationXYZ** node immediately before the **Cube** node. However, the rotation angle is specified in *radians* rather than *degrees*, so we must first convert our rotation angle into radians:

$$45 \times PI / 180 \approx 0.785$$

The rotation node is then added to the file as follows:

```
#Inventor V2.1 ascii
RotationXYZ {
   axis  Y
   angle 0.785
}
Cube {
}
```

Note how the rotation axis and angle are specified in the rotation node, and that the cube node appears after the rotation node.

The scale and translation node are used in a similar way. The example below shows two objects, one of which has a combined scale and translation applied:

```
#Inventor V2.1 ascii
Cube { }
Translation {
   Translation 2 0 0
}
Scale {
   scaleFactor 0.5 0.5 0.5
}
Cube { }
```

Note that the **Scale** node takes a *vector* of three values. These specify the scale factor on the X,Y and Z axes respectively. Similarly, the **Translation** node takes a vector which specifies how far to move the object on each of the X,Y and Z axes.

Example 3: Using Separators

There is a special node called the *Separator* which allows nodes to be grouped together in such away that any transformations, materials or other attributes are only applied to that group and will not affect other nodes in the scene graph. An example of this is shown below:

```
#Inventor V2.1 ascii
Separator {
   RotationXYZ {
      axis  Y
      angle 0.785
   }
   Cube { }
}
Cube { }
```

In the example above, we create a Separator node which contains a RotationXYZ node and a Cube node. The rotation will be applied only to the first cube in the scene. The second cube is not affected, since it lies outside the separator.

Example 4: Complex Surfaces

Here we provide a brief example of how more complex surfaces are represented within the Inventor file. You would not normally edit the structures described here by hand, but this information may be of use if you intend to write a script or program to generate such surfaces automatically.

Complex surfaces are described with a mesh of interconnected triangles which define the surface of the object. Usually, these take the form of a set of *triangle strips*. Each triangle strip consists of one or more triangles, connected in a continuous strip, and defined by a number of *vertices* (corner points). Within a strip, each triangle shares one edge (and two vertices) with its immediate neighbour.

The vertices (points) and triangle strips are listed separately in the file. We start by listing the X,Y,Z coordinates of each point, and then declare the triangle strip set. Within the triangle strip set, we list the index number of each vertex. This is much easier to demonstrate with an example:

```
#Inventor V2.1 ascii
Separator {
  Coordinate3 {
    point [
      0 0 0,
      1 0 0,
      1 1 0
    ]
  }
  IndexedTriangleStripSet {
    coordIndex [
      0, 1, 2, -1
    ]
  }
}
```

In the example shown above, the file begins with the **Coordinate3** node, whose **point** field lists the X,Y,Z coordinates of each triangle vertex. In this case, the vertices are located at (0,0,0), at (1,0,0) and at (1,1,0).

The next node in the file is an **IndexedTriangleStripSet**, which defines a single triangle in this case. Within this node, the **coordIndex** field defines one triangle strip, consisting of vertices 0, 1 and 2. The end of the triangle strip is marked by the special value -1. Note that the vertices are specified by a number which indicates their position within the vertex list, starting from zero. This is more efficient, because a single vertex can be used within a number of different triangle strips.

You will find more examples on the VRVision web-site, which include hundreds or thousands of triangles described in the same way. There is also a downloadable script (ivsurf) which generates surfaces of this type from within Matlab.

7. Initialisation File

There are many different preferences and settings that can be altered through the VRVision initialisation file (also referred to as the INI file). This is simply a text file that can be edited with most text editors. These settings are then loaded automatically when VRVision starts. Therefore, if you make changes to the INI file, you will need to restart VRVision for them to take effect.

The file is named:

```
vrvision.ini
```

It should be placed in the working directory of the VRVision plug-in. If the file cannot be located, an appropriate error message is output to the Matlab window.

The format of the file is basically the same as the standard Windows INI file format. It consists of a number of different *sections*, and each section contains one or more *keys*. For example, the settings that describe the width and height of the display screen are described in the INI file as follows:

```
[Screen]
Width=0.4
Height=0.3
```

In the example above, the section name is enclosed in square brackets **[Screen]**, and the keys are named **Width** and **Height**. This describes a display monitor with a width of 40cm and height of 30cm (since the values are specified in metres).

Each key is associated with a different setting or preference and has a particular value, which can be altered by the user. The names of the *sections* and *keys* are predefined and cannot be altered. However, the values can be changed, and it is not necessary to include all the supported keys. If a particular key is missing, the default setting will be used for that key.

If a section or key appears more than once, the last value to appear in the file will be used. We do not recommend that you do this, because it is redundant, and because it will be confusing for anyone reading the INI file later.

It is also possible to include comments in the INI file, which are useful to explain the meaning of a particular key, and to document why a particular value is used for a given key. Comments are denoted by using the semi-colon character at the start. For example, we might document the screen settings with the make and model of the monitor so that a user will know which monitor the INI file relates to:

```
[Screen]
; Iiyama Vision Master Pro 452
; This is the width and height of the display in metres
Width=0.365
Height=0.275
```

The remainder of this section lists the supported sections and keys, explains which values are acceptable for each key, and what effect this has on the behaviour of VRVision.

7.1. [Screen]

The [Screen] section contains settings that describe the physical size of the display screen. This should be the width and height of the visible image on the display surface in metres, rather than the outer dimensions of the monitor.

The monitor should first be set to the chosen display mode and refresh frequency, since this can affect the image size and proportions on screen. Any adjustments to the monitor settings such as width, height, position should then be finalised. When a satisfactory image is

obtained, the image size can then be measured using a ruler. Please note also that the ratio of the width and height specified here will determine the *aspect ratio* used for rendering.

The width and height are then specified in metre units, using the **Width** and **Height** keys:

```
[Screen]
Width=0.365
Height=0.275
```

In the example above, the displayed image is 365mm high and 275mm wide.

7.2. [Camera]

The camera settings control the position of a synthetic perspective camera, which represents the viewer. This is the camera that will be used when a static view position is used. When head-tracking is enabled, some of the camera parameters are modified automatically to account for the head position of the viewer.

The following section lists each key in **bold text**, followed by a brief explanation.

EyeSeparation

This specifies the distance between the eyes, in metres. This setting is also termed IPD or inter-pupillary distance. It is only used for stereoscopic 3D rendering, and has no effect on monoscopic perspective display. When stereoscopic rendering is enabled, two separate views are rendered by displacing the view position laterally from the camera centre position by half the eye separation to the left and right of centre.

For example, we can specify an eye-separation of 65mm as follows:

```
EyeSeparation=0.065
```

NearDist

This is the distance to the near clipping plane. It defines the position of the front face of the viewing frustum, nearest to the viewer. Any objects placed between the viewer and this plane will not be visible, since they will be clipped. The near and far clipping planes will affect the accuracy of the depth buffer (a mechanism in OpenGL which is used to determine whether each pixel rendered is visible or occluded by another surface in the scene). The depth buffer has a fixed resolution, which depends upon the graphics card and drivers. This resolution is divided over the entire viewing frustum between the near and far clip planes. Therefore, choosing clipping planes that tightly bound the scene will improve the depth buffer accuracy.

See also the FarDist key, which is used to set the distance to the far clipping plane.

An example to set up both clipping planes:

```
NearDist=0.1
FarDist=100.0
```

FarDist

This is the distance to the far clipping plane. It defines the position of the back face of the viewing frustum, far from the viewer. Any objects placed beyond the far clipping plane will not be visible, since they will be clipped. Please refer also to the **NearDist** key description for more detail about the influence of clipping planes on depth buffer resolution.

Position

This specifies the initial position of the viewer when the scene is viewed from a static viewing position. The position consists of three comma-separated values, specifying the X, Y and Z coordinates of the viewer. For stereoscopic display, this defines the midpoint between the two eyes. The origin is at the centre of the display surface. When facing the display, the X axis points right, the Y axis points up and the Z axis points out of the screen towards the viewer.

For example, to place the viewer position in the dead centre of the screen, at 50cm distance, the following settings would be used:

```
Position=0,0,0.5
```

Although the initial viewer position can be specified in the file, it is often overridden by setting the view position from a Matlab script, or by using head-tracking.

View

This defines the viewing direction vector. It is a unit-length direction vector that controls the direction in which the camera is aimed. Since the viewer will be facing towards the screen, this is normally set to (0,0,-1) to indicate that the camera is aimed along the –Z axis. It should not be necessary to alter this setting.

For example:

```
View=0,0,-1
```

Up

This defines the up direction vector. It is a unit-length direction vector that defines the up axis of the camera. Since the +Y axis of the screen points up from the point of view of a user, the up axis of the camera is also set to lie on the +Y axis. Therefore, this key is normally set to (0,1,0). It should not be necessary to alter this setting.

For example:

```
Up=0,1,0
```

Final notes:

If you are familiar with the use of *field of view* angles and *aspect ratio* settings for setting camera parameters, it is worth noting that in the case of VRVision, these are calculated on the basis of the screen dimensions and view position relative to the screen. For example, the aspect ratio is determined by dividing the screen width by the screen height.

7.3. [Tracker]

These settings are used to interface VRVision to an external tracking system, to support the head tracking feature. VRVision talks to this external hardware through a proprietary library called *TrackLib*. In order to connect to a particular device, TrackLib needs to know the device name, the physical port that it is connected to (for example COM1 serial port), and which tracked item is attached to the viewer or to the LCD shutter glasses. These settings are provided by the [Tracker] section of the INI file.

The following section lists each key in **bold text**, followed by a brief explanation.

Device

This specifies the name of the tracking system that we wish to use for head-tracking. This is passed directly to TrackLib, which searches for a match within the list of supported tracking systems. If a tracking system is found (by a case insensitive, sub-string search), it attempts to connect to that system. If the tracking system cannot be found, an error is displayed and the tracking option is disabled.

Some examples are shown below, which denote the Polhemus Fastrak, the Logitech 3D Mouse and the Vicon Real-time system respectively:

```
Device=fastrak
Device=3dmouse
Device=vicon
```

Port

This defines which port should be used to connect to the tracking system. It is a string of text, prefixed with **port:** to denote a local connection, or **net:** to denote a network connection, and followed by the specific port number or network address.

For example, a tracking system connected to a local serial port such as COM2 would have the following INI file setting:

```
Port=port:2
```

For a system such as the Vicon Real-Time server, this would be the network address of server. For example, if the server was running on a machine named *nemesis*, the following port would be specified:

```
Port=net:nemesis
```

Finally, if you know that the device is connected locally but aren't sure of the port number (or if the device is frequently moved around), you can ask TrackLib to attempt to detect it automatically:

```
Port=auto
```

GlassPort

Most tracking systems are able to track more than one item at any one time. For example, the Polhemus Fastrak can have four separate receivers, each of which can be used to track one object. It is therefore necessary to specify which of the available items is used to track the head position of the viewer for head-tracking.

For example, if we have a pair of LCD shutter glasses fitted with a Fastrak receiver, and that receiver is plugged into connector 1 on the front panel of the Fastrak, we would specify that item 1 is used to track the glasses by adding this line to the [Tracker] section of the INI file:

```
GlassPort=1
```

7.4. [TrackerXForm]

When the tracking system reports the position of a tracked object to VRVision, it will almost certainly use a different coordinate system to that of the display. For example, the tracking system origin for the Polhemus Fastrak will be located at the centre of the magnetic transmitter, not the centre of our display surface. Furthermore, the X, Y and Z axes will not usually be aligned with those of the display.

For this reason, VRVision allows you to specify a transformation matrix, which defines how to transform from the tracking system coordinate frame to that of the display. This is specified in terms of the unit-length direction vectors of the **X**, **Y** and **Z** axes, and a position vector **P** that defines the translation component.

For example, the settings below were used for a Vicon tracking system, where the tracking system X axis was aimed towards the screen, the Y axis pointed left, and the Z axis pointed up. The coordinate axes in VRVision are completely different, with the X axis pointing right, the Y axis up, and the Z axis pointing out of the screen. The tracking system origin was also located 1.2m vertically below screen centre at 3m distance. The transformation matrix given below allows VRVision to transform between these two very different coordinate spaces:

```
[TrackerXForm]
X=0,0,-1    ; ViconX = -ScreenZ
Y=-1,0,0    ; ViconY = -ScreenX
Z=0,1,0     ; ViconZ = +ScreenY
P=0,-1.2,3  ; -1.2m on Y axis, 3m on Z axis
```

If the tracking system axes happen to match those of VRVision, and only a simple position offset is required, the X, Y and Z vectors would be specified as shown below:

```
X=1,0,0
Y=0,1,0
Z=0,0,1
```

Then the P value can be used to specify the X, Y and Z position offset.

7.5. [GlassesXForm]

If a tracking receiver or target is attached to a pair of LCD shutter glasses, or perhaps to a headband, it can be used to track the position of the viewer. However, the tracking system will report the position and orientation of the object being tracked, whereas VRVision requires the position and orientation of a synthetic camera located at the midpoint between the eyes of the viewer. The [GlassesXForm] section allows you to specify the transformation from the tracked object to the midpoint between the eyes.

As with the [TrackerXForm], the transformation matrix is specified in terms of three unit length direction vectors of the **X**, **Y** and **Z** axes, and a position vector **P**.

For example, when the Vicon system reports the location of the glasses, the +X axis is aligned with the viewing direction, the +Y axis points left and the +Z axis points up. However, our synthetic camera is arranged so that the viewing direction is along the –Z axis towards the screen, the up vector is the +Y axis and the +X vector points to the right. For this example, the origin of the object was located at the midpoint of the eyes, so that no position offset is needed.

We can specify a transformation between these two coordinate systems as follows:

```
[GlassesXForm]
X=0,-1,0       ; CameraX = -ViconY
Y=0,0,1        ; CameraY = ViconZ
Z=-1,0,0       ; CameraZ = -ViconX
P=0,0,0        ; No position offset needed in this case
```

7.6. [Scene]

This section contains various settings that determine which scene file is loaded by default, and how it will be displayed within VRVision. For example, it is possible to enable a default light source, to scale the scene and to automatically centre the scene at the origin.

The following section lists each key in **bold text**, followed by a brief explanation.

File

This specifies the name of the scene file to load by default. It can be any suitable OpenInventor 2.1 or VRML 1.0 format file. When VRVision is started from within Matlab without any parameters, this is the file that will be loaded.

For example:

```
File=scene.iv
```

Headlight

This option can be used to enable a simple directional light source, aimed along the –Z axis into the scene. If you wish to specify your own light sources within the scene file, it is recommended that you disable this headlight.

For example:

```
Headlight=1 ; enable the light
Headlight=0 ; disable the light
```

Scale

This specifies the scale of the scene for display purposes. If the object size is carefully defined, and the scale and screen size are specified correctly in the INI file, it is possible to display an object at actual size.

For example, if the screen size is 40cm by 30cm, and our scene file contains a 20cm cube, then the scale can be set to 1 to display that object on screen at actual size:

```
Scale=1
```

However, if scale is not important and you want the object automatically scaled to fit on the screen, you can set the scaling mode to automatic:

```
Scale=auto
```

The scale factor is also commonly used to scale between units such as imperial and metric, or to scale an object relative to the original size in the scene file, for example:

```
Scale=0.5
```

AutoCentre

If an object described in a scene file is to appear at the centre of the screen, it should be located at the origin (0,0,0), since the origin in VRVision is located at screen centre. However, not all scene files will necessarily be defined to lie at the origin. The **AutoCentre** option can be used to automatically move the scene to the origin when it is loaded. This works by calculating the centre of the *bounding box* of the scene (the smallest axis aligned box that completely encloses the scene), and translating or moving the scene by that amount so that it is relocated at the origin.

For example:

```
AutoCentre=0   ; don't move the scene
AutoCentre=1   ; move the scene to the origin
```

Note that the scene will also rotate around the origin when using joystick or mouse movement functions. This option can then affect whether an object will rotate about the origin of the object, or the centre of the bounding box. Also refer to the **RotateFirst** option.

RotateFirst

This option forces the X and Y rotation nodes to be inserted before the Translation node that is used to implement the auto-centre feature. This means that if both the AutoCentre and RotateFirst options are enabled, the scene will be automatically repositioned at the origin and then rotated. This is explained in more detail in section 6.2.

For example:

```
RotateFirst=0   ; rotate after translation
RotateFirst=1   ; rotate before translation
```

UnderlayBlit

VRVision is able to automatically capture the contents of the screen before it starts (see the *UseUnderlay* function for more information), and to display this as a textured background behind the objects that it renders. VRVision implements two different methods to achieve this, since the performance and quality of each may vary from one graphics card to another. This INI file option selects which implementation is used:

```
UnderlayBlit=0       ; Use texture mapping method
UnderlayBlit=1       ; Use blit / block-transfer method
```

If a particular method does not perform well on your chosen graphics card, you can try changing this option to see if it improves the speed or quality.

ForceTopMost

If enabled, this option causes VRVision to force itself on top of all other windows on the desktop. On the Windows operating system, it does this by applying the top-most window property. If this option is disabled, VRVision will still raise itself above other windows, but in a less forceful way (which is the default).

```
ForceTopMost=0       ; raise window to top politely
ForceTopMost=1       ; force window on top
```

ForceStereoPF

When using stereoscopic display in OpenGL, VRVision automatically creates a window with a *stereo pixel format*. If the *ForceStereoPF* option is enabled, this will cause VRVision to always use a stereo pixel format, regardless of whether the stereoscopic display is enabled. For example, in an experiment this will ensure that the LCD shutter glasses are enabled (i.e. flickering) even when displaying monoscopic images. This means that an experimental participant can wear the glasses in both monoscopic and stereoscopic conditions, and will therefore experience similar flicker and display brightness in both cases.

```
ForceStereoPF=0      ; use stereo only in stereoscopic mode
ForceStereoPF=1      ; always use stereo, even for monoscopic
```

Note that there is a performance cost associated with the use of a stereoscopic pixel format, since it is necessary to render the scene twice, once for the left eye and once for the right eye. Therefore, this option is only recommended for special cases such as the example described above.

ShowCursor

This option determines whether the mouse cursor is visible when VRVision runs in fullscreen mode. The mouse cursor is hidden by default.

```
ShowCursor=0   ; hide mouse cursor (default)
ShowCursor=1   ; show the mouse cursor
```

ShowHud

This option can be used to turn the ‘head up display’ on and off, which displays statistics about the rendering performance. Currently, this is limited to a simple display of the frame rate, indicating the number of frames per second that can be achieved for a particular scene. You will normally want to leave this option disabled, but it can be useful to know the current frame rate when setting up an experiment, or to see what effect a particular feature (such as stereo or anti-aliasing) has on performance.

```
ShowHud=0      ; hide head up display
ShowHud=1      ; show head up display
```

IVCacheMin

This is used with a customised version of the OpenInventor graphics library to set the IV_AUTO_CACHE_MIN environment variable. This affects the caching policy of OpenInventor, and can improve performance in some cases by allowing it to cache complex scenes by constructing an internal *display list* for more efficient rendering.

For example:

```
IVCacheMin=1000      ; alter OpenInventor cache limit
```

CaptureMouse

This option determines whether VRVision uses *mouse capture* within Windows to capture mouse messages:

```
CaptureMouse=0 ; don’t capture mouse (default)
CaptureMouse=1 ; capture mouse input
```

7.7. [Joystick]

This section contains settings that affect the behaviour of the joystick or game controller. These settings influence the sensitivity of the joystick when it is used to manipulate objects.

The following section lists each key in **bold text**, followed by a brief explanation.

Deadzone

Most joysticks are sprung so that the stick will return to a zero or centre position when released. However, they do not always return exactly to centre, and may report a small non-zero position value even when the user is not applying any pressure to the stick. The *Deadzone* parameter allows you to specify a lower limit value, below which the joystick movement will be ignored. Increasing the Deadzone value means that the user will have to push the joystick further from centre before the scene will begin to move.

The acceptable range of the Deadzone value is between 0 and 1, but is typically a very small percentage of this range such as 0.1. This is because the full scale for the joystick movement is in the range -1 to +1. Therefore, a Deadzone value of 1 would disable the joystick completely.

For example:

```
Deadzone=0.1
```

Some joysticks already implement this method at a driver level, in which case a Deadzone value of zero can be specified to disable this feature in VRVision.

Scale

The scale parameter allows the sensitivity of the joystick to be adjusted. Increasing the scale will cause the scene to move faster in response to the same amount of stick movement. After clamping the joystick values within the Deadzone limits described previously, they are multiplied by the Scale parameter to determine the rate of scene movement.

Therefore, reducing the scale will make the stick less responsive, and increasing it will make the stick more responsive. Some joysticks may offer similar parameters within the control panel and device settings.

For example:

```
Scale=0.1
```

8. Hardware for Stereoscopy

This section outlines some of the hardware requirements, if you wish to use the stereoscopic feature within VRVision. Stereo support has improved considerably on graphics cards, but can still be problematic in some cases. However, with the right choice of equipment, it is possible to achieve a good quality stereoscopic display on relatively inexpensive PC based commodity hardware.

8.1. Display Devices

There are many possible methods for displaying stereoscopic imagery, some of which are listed here briefly:

1. CRT monitor, with LCD shutter glasses.
2. Stereo capable CRT video projector, with LCD shutter glasses.
3. Stereo capable DLP video projector, with LCD shutter glasses.
4. Pair of LCD/DLP projectors with polarising windows, and polarised glasses.
5. CRT/LCD/DLP with “Z-Screen” polarizer, and polarised glasses.
6. CRT/LCD/Plasma monitor with surface mounted lens array.
7. CRT/LCD/Plasma monitor with grating (‘Barrier’ stereo method).

This list is by no means comprehensive, and the range of commercially available stereo display systems continues to expand. However, arguably the most commonly used display system for stereoscopy on the desktop is the combination of LCD shutter glasses and a CRT monitor. This is the solution that we will describe here, along with some examples of suitable glasses and display monitors.

Many of the techniques described above will function with VRVision, providing that the device in question is compatible with the OpenGL quad-buffer stereo format. However, there are some displays (certain of the new free viewing flat panels for example), that will not be directly compatible.

Shutter Glasses

There are several different varieties of LCD shutter glasses available, and a comprehensive review is not possible here. However, two suitable models that are worth considering are the CrystalEyes (StereoGraphics Corp.), and the nuVision 60GX (MacNaughton Inc.). These both have reasonably large LCD panels (so as not to restrict the field of view of the user), are relatively comfortable to wear, and have good compatibility with most workstation graphics cards that have stereo support.

When buying glasses, it is important to check for compatibility with the graphics card in question. The preferred interface is the 3-pin VESA stereo DIN connector. This is simply a miniature 3-pin DIN socket, which provides power to the glasses, and a synchronisation signal to switch the LCD panels at the appropriate moment. If you have a graphics card that does not offer the 3-pin VESA stereo connector, then you will need an external interface of some kind to derive the synchronisation signal from the VGA connector. For example, the StereoEnabler (StereoGraphics Corp.), and the nuVision 60GX-NSR emitter (MacNaughton Inc.) both connect to the VGA port of a graphics card. You will need to check that your graphics card and drivers are compatible with these devices before buying.

Technical information on the glasses, and compatibility issues, is available from the following sources:

http://www.stereographics.com	(CrystalEyes glasses)
http://www.nuvision3d.com	(nuVision glasses)
http://www.stereo3d.net	(reviews, information)
http://www.stereovision.net	(forum, links, news)

Monitors

The shutter glasses function by alternately blocking the left and right eye using liquid crystal shutter panels, in synchronisation with the display. The left and right eye images are displayed alternately, so that each eye will receive a different image, resulting in a stereo effect.

For this to work, the image must 'persist' on the display for a very short time, which in practice means that only CRT monitors are suitable. Unfortunately, LCD flat panel monitor and plasma displays are currently too slow to be compatible with shutter glasses. If the image persists for too long, there will be no stereo effect, or at least a very severe 'ghost' image (this term means that the left eye image can be partially seen on the right eye, and vice versa). Therefore, you should select a good quality CRT monitor, preferably one with a short persistence phosphor.

The second problem is that the vertical refresh frequency of the monitor is effectively halved, so that flicker might be perceived by the user. This can be avoided by increasing the vertical refresh frequency of the monitor. However, the maximum frequency available will depend upon the display resolution. For example, a monitor may support 100Hz refresh at 1024×768, but only 75Hz at 1280×1024. Therefore, you will need to decide what resolution and refresh rate you need before selecting a monitor.

Increasing the vertical refresh rate will decrease the flicker. The maximum vertical refresh rate is usually limited by the monitor, rather than the graphics card. You should aim to have a vertical refresh rate of at least 100Hz, preferably 120Hz if possible. Also, it is not recommended to drive a monitor outside the limits recommended by the manufacturer, since this can result in permanent damage.

Finally, you will see a reduction in brightness when viewing stereo images when compared to mono images. This is due to the attenuation of the LCD shutter (which does not become perfectly transparent when open), and since each eye will be exposed to the image for only 50% of the time (the LCD shutter is opaque for the remaining time). In an experimental study that compares mono and stereo viewing, this will need to be considered.

8.2. Graphics Cards

This section describes some of the graphics cards that are suitable for use with VRVision, and attempts to address some of the technical issues involved in using these cards. Please note that the graphics industry moves very quickly; it is likely that the cards described here will soon be replaced by a new generation.

The general requirements are as follows:

1. Must support hardware accelerated OpenGL 1.2 or above.
2. Must support "quad-buffer OpenGL stereo", that is to say: it must be possible to create an OpenGL window with a stereo pixel format. In general, these tend to be classed as "workstation" graphics cards.
3. The graphics card must be compatible with your choice of stereoscopic display hardware. For example, if your LCD shutter glasses have a 3-pin VESA stereo

connector, then you must use a graphics card that features this connector (or you must use an external adaptor).

When selecting a graphics card, be aware that many consumer class graphics cards support a specific type of stereo 3D that is designed for use in games. This does not necessarily mean that these cards support true *quad-buffer stereo* in OpenGL, which is required for VRVision.

At time of writing, there is an excellent summary of compatible 3D hardware available on the StereoGraphics web-site:

http://www.stereographics.com/support/boards/brd-chrt.htm

The 3DLabs Wildcat family

The 3Dlabs Wildcat 3 (6110/6210) and Wildcat 4 (7110/7210) are workstation class graphics cards that offer accelerated OpenGL support, and feature a 3-pin VESA stereo connector. These cards are directly compatible with most stereo shutter glasses, such as CrystalEyes (StereoGraphics Corp.) and nuVision 60GX (MacNaughton Inc.). However, they are relatively expensive, workstation class graphics cards.

For detailed specifications and reseller information, please visit the manufacturer web-site:

http://www.3dlabs.com

In order to use stereo support on these cards, you must select a “Frame Sequential Stereo” display mode using the Display Settings dialog.

The nVidia Quadro/GeForce family

The nVidia Quadro family is targeted at professional workstation market, and offers excellent OpenGL performance and stereo support at a competitive price. The nVidia GeForce is based on the same chip set, but targeted at the consumer market, and lacks some of the features of the professional card (such as quad-buffer stereo support). In both cases, driver support is excellent, with a good OpenGL implementation. The Quadro cards are available with 3-pin VESA stereo connectors, making them compatible with most stereo shutter glasses, including CrystalEyes (StereoGraphics Corp.) and nuVision 60GX (macNaughton Inc.).

For cards that do not feature the 3-pin VESA stereo connector, it is still possible to connect stereo shutter glasses by using an external interface box such as the StereoEnabler (StereoGraphics Corp.), which attaches to the VGA connector of the graphics card and converts this to a 3-pin VESA output. This is only possible if the graphics driver is able to place the appropriate stereo synchronisation signal on the VGA port, for example the “blue line code” that is used by StereoGraphics products.

There is more information available on the StereoGraphics web-site:

http://www.stereographics.com

When installing the card, you have the choice of either installing the drivers that came with the card, or downloading the latest drivers from the manufacturer. In our experience, the best option is to download the latest nVidia Detonator drivers from the nVidia web-site:

http://www.nvidia.com

Having installed the drivers, you will find that quad-buffer stereo is disabled by default. In order to use stereo, you must enable the option in the display settings dialog. There follows an example of how to configure an nVidia Quadro card to enable stereo under Windows 2000.

First, open the *display properties* dialog (Figure 1), either by right clicking on the desktop and selecting **Properties**, or by opening the *control panel* and double-clicking on **Display**.

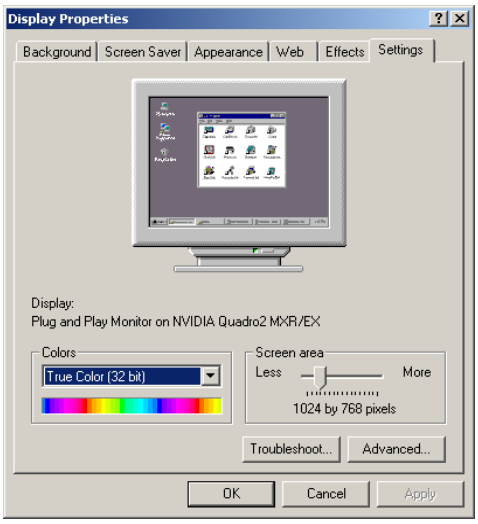


Figure 1. Display Properties Dialog

In the display properties dialog (Figure 1), click on the **Advanced…** button, to open the advanced properties dialog (Figure 2).

You should click on the tab that lists the name of your graphics card, which in this example is a Quadro2 MXR/EX. Under Display Adapter Information (see Figure 2) you should see your Graphics Processor identified as a Quadro (if not, then you are unlikely to have stereo support).

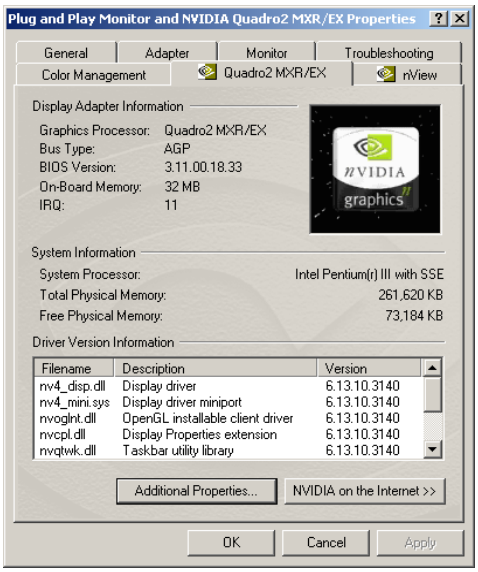


Figure 2. Advanced Properties Dialog

Click on the **Additional Properties…** button to proceed, and you should then see the additional properties dialog (Figure 3). You will need to click on the tab for OpenGL settings, to see the options shown below.

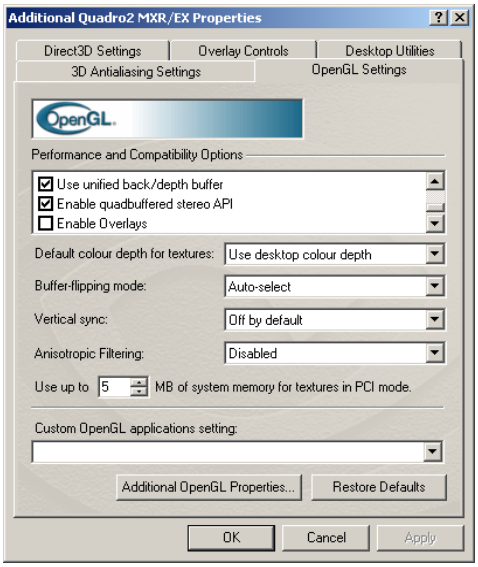


Figure 3. Additional OpenGL Properties

At this point, you should make sure that 'quadbuffered stereo API' is **enabled**, and 'overlays' are **disabled**. Your settings should match those shown in the upper white box in Figure 3. Having made these changes, you should be able to run VRVision in stereo. Note that it may be necessary to restart Matlab and VRVision before the changes take effect.

While you are in the Display Properties dialog, you should change the vertical refresh frequency to the maximum that your monitor can safely support for the current display mode. This is changed using the Monitor tab as shown in Figure 4. Please check which modes are supported by your monitor before changing this setting and test the display mode before applying changes.

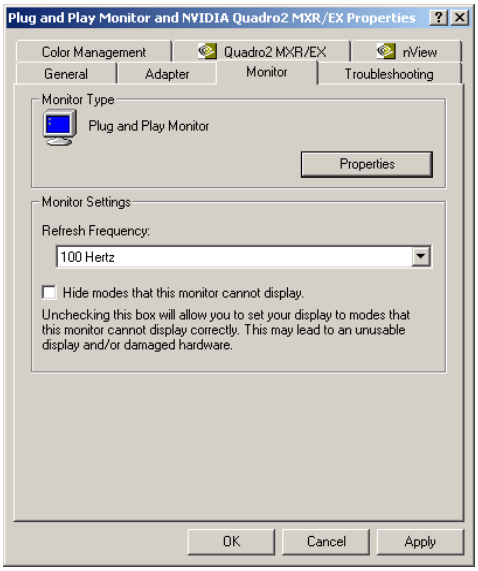


Figure 4. Monitor Vertical Refresh Frequency

9. Tracking Systems

VRVision supports head tracking, if a suitable tracking system is available, and has been properly configured. This feature can be enabled and disabled as required by the *UseHeadTrack* function.

When head tracking is enabled, the tracking system is used to measure the position of the shutter glasses, and the approximate position of the left and right eyes is calculated from this. The display is dynamically updated to provide an appropriate projection, based on the head position of the viewer. This feature is available in both monoscopic and stereoscopic display modes. When disabled, the fixed viewing position is used (this is read from the INI file by default, and can be overridden by the SetViewPos function from Matlab).

When using a tracking system, most of the configuration settings are read from the INI file, since they are not usually changed during the course of an experiment. These settings include information about which communication port the tracker is connected to, and calibration settings that account for the placement of the tracker relative to the screen and the glasses.

9.1. Supported Tracking Systems

At present, the following tracking systems are supported:

1. Ascension Flock of Birds (electromagnetic)
2. Vicon Real Time Server
3. Polhemus Fastrak (electromagnetic)
4. Logitech 3DMouse (ultrasonic)

We have access to all the systems listed above, and are prepared to support them. If problems are reported with any of the systems above, and can be reproduced locally, then we will try and provide a solution. This is done as a courtesy, and does not constitute a guarantee.

The following systems are partially supported, or unsupported. That is to say, they have either not been extensively tested with VRVision, or they are still under development. In some cases, we do not have access to the system, so continued development and testing is not possible.

1. Image Guided Technologies, Flashpoint 5000 (optical)
2. Northern Digital, Polaris
3. Qualisys Track Manager Real Time
4. Intersense (various)

9.2. Configuration File Settings

There are three separate sections in the INI file that are used to configure the tracking system for use with VRVision:

```
[Tracker]      ; tracker/communication settings
[TrackerXForm] ; transform: transmitter/screen
[GlassesXForm] ; transform: receiver/glasses
```

These are documented in section 7, and briefly summarised here.

Sample: Logitech 3D Mouse

Here is a complete sample configuration for Logitech 3D Mouse on COM1. Note that the rest of the INI file has been omitted for reasons of space, and only the three sections that relate to the tracking system are shown here:

```
[Tracker]
Device=3dmouse          ; name of tracking system to use
```

```
Port=port:1              ; which COM port to use (or ‘auto’)
GlassPort=1              ; which port the glasses are on

[TrackerXForm]
X=1,0,0                  ; direction vectors for transmitter
Y=0,1,0
Z=0,0,1
P=0,0.466,0.295          ; translation for transmitter

[GlassesXForm]
X=1,0,0                  ; direction vectors for receiver
Y=0,-0.89879,-0.43837
Z=0,0.43837,-0.89879
P=0,-0.08,0.04           ; translation for receiver
```

The TrackerXForm specifies the transformation between the tracking system transmitter and the screen centre. In this case, the transmitter was mounted centrally on top of a 19” flat screen monitor, and the axes were aligned with the monitor. Therefore, only a position offset (translation) is needed in the example above.

The GlassesXForm specifies the transformation between the tracking system receiver, and a point that lies halfway between the two eyes of the viewer. In this case, the receiver was mounted on the top of a pair of CrystalEyes glasses, facing towards the transmitter, and tilted backwards towards the forehead. Therefore, the direction vectors are used to account for this rotation on the X axis. Since it is a simple X axis rotation, you will notice that the X direction vector is unaffected in the example above. As with the transmitter, a position offset is also needed.

Sample: Ascension Flock of Birds

Here is a complete sample configuration for an Ascension Flock of Birds (with a single receiver) on COM1. Note that the rest of the INI file has been omitted for reasons of space, and only the three sections that relate to the tracking system are shown here:

```
[Tracker]
Device=bird              ; name of tracking system to use
Port=port:1              ; which COM port to use
GlassPort=1              ; which port the glasses are on

[TrackerXForm]
X=-1,0,0                 ; direction vectors for transmitter
Y=0,0,-1
Z=0,-1,0
P=0.51,-0.27,0.38        ; translation for transmitter

[GlassesXForm]
X=0,0,-1                 ; direction vectors for receiver
Y=0,-1,0
Z=-1,0,0
P=0,0,0.07               ; translation for receiver
```

The [TrackerXForm] specifies the transformation between the tracking system transmitter and the screen centre. In this case, the tracker (X,Y,Z) axes were aligned with the screen (-X,-Z,-Y) axes respectively. Therefore, the X axis vector in the [TrackerXForm] is set to the –X axis (-1,0,0), the Y axis vector is set to the –Z axis (0,0,-1) and the Z axis vector is set to the –Y axis (0,-1,0).

The position offset P in the [TrackerXForm] accounts for the position of the transmitter relative to screen centre. In this case, the transmitter origin was located 51cm right of the screen centre, 38cm in front of the screen plane, and 27cm below the screen centre.

The GlassesXForm specifies the transformation between the tracking system receiver, and a point that lies halfway between the two eyes of the viewer. In this case, the receiver was mounted on the right arm of a pair of CrystalEyes glasses, facing towards the monitor, with the base of the receiver mounted flush against the outside of the arm of the glasses. The receiver cable was taped to the end of the arm, just above the ear.

The viewing direction of the user was assumed to be along the X axis of the receiver, but the camera in our scene looks along the –Z axis. Therefore, the X vector in the [GlassesXForm] is set to point along –Z axis (0,0,-1). Similarly, the up vector of the camera is on the +Y axis, whereas the up axis of our receiver is –Y. Therefore the Y vector in the [GlassesXForm] is set to the –Y axis (0,-1,0). Finally, the Z axis of our receiver points along the –X axis, so the Z vector is set to the –X axis (-1,0,0).

It's important that these three vectors form an orthogonal, right-handed coordinate frame.

There is a position offset of 7cm to account for the fact that the receiver is placed some distance to the right of the eye centre.